Geothermal

Mission Supporting Goals and Objectives

Program Mission

The mission of the Geothermal Energy Program is to work in partnership with U.S. industry to establish geothermal energy as a sustainable, environmentally sound, economically competitive contributor to the U.S. and world energy supply.

Program Goals and Objectives

Working in close cooperation with its stakeholder community, the Geothermal Energy Program has developed a set of goals for the year 2010, as specified in the Geothermal Energy Strategic Plan (June 1998) which has been endorsed by U.S. Industry. These goals, include:

- Strategic Goal 1 — Electric Power Generation: Supply the electrical power needs of 7 million U.S. homes (equivalent to 10,000 MW of generation).
- Strategic Goal 2 — Direct Use Applications and Geothermal Heat Pumps: Supply the heating, cooling, and hot water needs of 7 million U.S. homes (equivalent to saving 4,000 MW of generation).
- Strategic Goal 3 — International Geothermal Development: Meet the basic energy needs of 100 million people in developing countries through sales of U.S. technology and services (equivalent to 10,000 MW of generation).
- Strategic Goal 4 — Science and Technology: Accelerate the development of U.S. geothermal science and technology to maintain world leadership.
- Strategic Goal 5 — Future Geothermal Resources: Develop new technology to meet 10 percent of U.S. non-transportation energy needs within the following 25 years.

A corollary technical objective is to reduce the levelized cost for geothermal electric power generation from the current $0.035/kWh to less than $0.03/kWh by the year 2010, a reduction of 25% from 1997 levels. This objective derives from Strategic Goal 1. Overall, the strategic plan contains some 18 objectives derived from the goals.

Strategic Approach

The Geothermal Energy Program directly supports four of the five goals of the DOE Comprehensive National Energy Strategy (1998): (1) Geothermal heat pumps will significantly increase energy efficiency in the building sector, including Federally-owned buildings. (2) Geothermal electricity will contribute 10,000 MW to the overall goal for renewables of at least 25,000 MW by 2010, while helping to promote energy production and use in ways that respect health and environmental values. (3) Enhanced

Geothermal Systems technology offers an attractive, long-term option for an energy resource that is extremely plentiful with few adverse effects. And (4) the Program expects to accelerate the deployment of clean, safe, and efficient geothermal systems around the world. The Department's Comprehensive National Energy Strategy supports the development of renewable technologies, such as geothermal energy, to increase domestic energy production in an environmentally-responsible manner.

The geothermal power plants at The Geysers in northern California.

The Program's R&D activities closely align with its mission and strategic goals. With improved exploration methods, industry will locate and characterize new geothermal fields more accurately, reducing the risk of development. Better technology for drilling wells will make it possible to access deeper resources and reduce costs, thereby expanding the economic resource base. Advances in energy conversion will establish air-cooled binary technology as a means of generating competitively-priced electricity from more plentiful lower-temperature resources. Studies of reservoir behavior will improve the management of geothermal fields, allowing fields to operate for over 100 years as sustainable commodities.

Geothermal electric generation projects are capital-intensive enterprises, with the major expenses being incurred before the plant begins to produce revenue. The high-cost components of a geothermal development project include (1) drilling of exploration, production, and injection wells, and (2) plant equipment and construction. The primary risk in a geothermal project is confirmation of a viable reservoir, which usually requires extensive drilling and well testing. To reduce the risks and costs in geothermal development, the Program's research strategy involves:

Southeast Geysers Effluent Pipeline Project

In late 1997, a novel project to generate electricity from treated wastewater began in Northern California. The geothermal industry and various government agencies, including DOE, joined forces to build the Southeast Geysers Effluent Pipeline. The pipeline project takes treated wastewater and uses it to produce additional steam at The Geysers, the largest geothermal power plant development in the world.

Labeled "environmentally superior," the project consists of a 29-mile, 20-inch diameter pipeline that carries 7.8 million gallons of water per day from the Lake County Sanitation District in Clearlake to The Geysers. At The Geysers, the secondarily-treated water is injected deep into the hot rocks that comprise the geothermal reservoir. The water boils into steam which is recovered by production wells and then used in turbine/generator machinery to generate electricity. The steam allows the generation of up to 70 megawatts of additional power.

Knowing where to inject the treated wastewater is important for maximizing steam production. DOE marshaled the resources of its national laboratories and other contractors to understand fluid flows and chemical interactions deep within the reservoir, thereby assisting industry in determining an optimum injection strategy.

A public/private partnership between the sanitation district representing the communities of Clearlake, Lower Lake, and Middletown, and three Geysers steam suppliers made the project a reality. This project successfully brought together the sanitation district, which was searching for a way to dispose of wastewater, and the steam suppliers, who needed additional sources of water for their depleted reservoir. Both Federal and state governments were instrumental in providing partial funding. The project was honored with three awards in 1998: the California State Association of Counties 1998 Challenge Award of Merit, the California Governor's 1998 Environmental & Economic Award of Recognition, and the Water Reuse Association of California 1998 Award of Merit.

- improving technologies for exploration, detection of fractures and permeable zones, well siting, and fluid injection;
- decreasing the cost of drilling and completing geothermal wells; and
- reducing the capital, operation, and maintenance costs of geothermal power plants.

The proposed activity level is sufficient to maintain geothermal R&D at a level of effort that results in continuous technology advances. A few new initiatives, such as the Geothermal Advanced Drilling System (GADS), may produce revolutionary changes which will accelerate development and use of geothermal resources, providing a reliable alternative source capable of supplying a significant fraction of the nation's energy needs.

The U.S. geothermal industry is too small to maintain independent research capabilities. Also, the international competition for geothermal power development projects is intense. The chief competition comes from Italy, Japan, and New Zealand, but other countries have become active as well. If the U.S. industry is to maintain its current world-leadership position, create new jobs, and help to expand the U.S. economy, assistance from the DOE Program is vitally important.

The proposed R&D program is based upon the Department's interaction with industry stakeholders and geothermal experts at universities and the national laboratories to develop a balanced portfolio of core (basic and applied) research, and well-focused technology development thrusts. The budget supports the five goals of the Geothermal Energy Strategic Plan. Cost-shared activities in reservoir technology, exploration, drilling, and energy conversion will leverage the R&D funds and facilitate technology transfer.

Annual royalties paid to the Government for geothermal power production on Federal lands exceed the Program's budget. For example, since 1995 the geothermal budget has averaged about $30 million, whereas royalty payments have exceeded $40 million annually. A recent study suggests that with continued development of geothermal resources those payments could double within 15 years.

Program Benefits

Metric	FY 2000	FY 2010	FY 2020
Primary Energy Displaced (Quads)	0.05	0.18	0.25
Energy Savings ($ Billions)	0.11	0.46	0.71
Carbon Displaced (MMTCE)	1.08	3.09	4.06

Scaled for the year 2004, these benefits correspond to supplying the electrical power needs of 2.5 million U.S. homes (3,300MW electricity generation capacity (MWe)) and 40 million people in developing countries using U.S. technology (4,000MWe).

Performance Measures

FY 2000 Performance Measures

- Complete a five-MW Kalina Cycle (advanced heat recuperation technology) demonstration geothermal power-plant.
- Complete laboratory evaluation of a direct contact condenser for binary cycles using mixed working fluids.
- Select one partner for demonstration of small-scale distributed power generation.
- Initiate development of high-temperature, “keep-a-live” battery prototype for powering electronic equipment in wells.
- Perform initial field test validating the usefulness of a high-speed data link for well drilling.
- In cooperation with the geothermal industry, complete testing and evaluation of three alternative methods for producing seismic energy for application to 3D seismic imaging of fractured geothermal reservoirs, and incorporate the best source technology in an exploration system to locate and characterize new geothermal fields.
- In joint DOE-industry projects, examine and assess a variety of chemicals for use as tracers for the flow of injected fluid through geothermal reservoirs, and confirm five new tracers that are environmentally compatible, stable at high temperatures, and detectable in minute quantities.

FY 2001 - 2006 Performance Measures

- Complete demonstration of economic benefits of a Kalina cycle in a geothermal power plant application.
- Complete demonstration of small-scale distributed power generation.
- Complete development and field testing of high-temperature, downhole fluid sampler.
- Initiate full scale validation and verification of a high-speed data link which will be ready for commercial use by 2006.
- Provide the geothermal industry with a scientific analysis of the effectiveness of 3D seismic surveys in the exploration for fractured geothermal reservoirs, and give guidance on the economic value of 3D seismic surveys versus other exploration methods.
- Through joint testing with industry, provide an evaluation of the borehole electromagnetic imaging tool to locate productive fractures in geothermal reservoirs and supply the computer algorithms for rapid and accurate interpretation to allow decisions to be made during drilling.

Significant Accomplishments and Program Shifts

Pre-FY 1998 Accomplishments

- Demonstrated the use of slimhole drilling for geothermal exploration, thereby reducing exploration drilling costs by 30 to 50% relative to standard 1995 technology.
- Developed the original design bases for polycrystalline diamond compact (PDC) drill bits. These were being used in about 40 percent of oil and gas drilling worldwide as of 1997.
- Developed technologies that achieved up to 10% improvements (relative to 1990 levels) in efficiency of power plants operating with high non-condensible gas concentrations (at The Geysers, CA) and with reduced brine temperatures (at Mammoth, CA).
- Increased annual installations of geothermal heat pumps by over 20% in 1997 through a collaborative public outreach effort with the Geothermal Heat Pump Consortium

FY 1998 Accomplishments

- Baker Hughes, a major drilling services company, signed a licensing agreement with Sandia National Labs for wireless telemetry technology to communicate with tools placed in wells up to two miles deep.
- Core-tube data logger was commercialized by Boart Longyear, a supplier of drilling equipment, for geothermal and mineral exploration activities.
- Completed conceptual design of an air-cooled trilateral cycle power module for village power applications.

FY 1999 Planned Accomplishments

- Complete development of specialized drilling equipment under the NADET program.
- Complete field test of insulated drill pipe with an industrial partner to provide much lower bottomhole fluid temperatures during drilling to increase tool life, improve drilling mud properties, and improve the operating environment for downhole electronics.
- Complete design and testing of three seismic source instruments to generate shear waves for geothermal 3-D seismic exploration.
- Complete design of a borehole electromagnetic logging tool to identify productive fractures.
- Field test improved-efficiency power generation technologies, including small-scale power modules, to increase electrical power output per pound of brine by 20%.
- Establish geothermal heat pumps as the technology of choice for schools, and install 10,000 units in Federal buildings.

FY 2000 Planned Accomplishments

- Complete improved injection techniques for proper fluid management in order to operate a geothermal field in a sustainable mode for over 100 years.

- Assist the U.S. geothermal industry, through cost-shared (50:50) field testing and evaluation research, in the development of two 40 megawatt power plants in the United States.
- Select an industrial partner for the cost-shared (50:50) development of an Enhanced Geothermal System at a working U.S. geothermal field.
- Evaluate the use of 3D seismic exploration methods to locate and characterize new geothermal fields through collaborative research with industry.
- Develop smart systems that integrate individual geophysical methods and provide a more reliable exploration target.
- Field test a new, innovative electromagnetic exploration tool to locate subsurface fractures.
- Complete field testing of improved PDC bits designed for hot, hard rock to double bit life and penetration rates thereby reducing well costs by about 5%.
- Complete a field test of a hard-wired, high-speed data link as a component of the Geothermal Advanced Drilling System to continually monitor and control drilling functions downhole.
- Complete development of high-temperature unshielded electronics and batteries for logging tools that will operate at temperatures exceeding 300°C.
- Complete construction of an 8MW Kalina cycle demonstration power plant that uses advanced heat recuperation technology. The non-Federal share of costs of this demonstration is over 60%. Advanced heat recuperation technology increases the energy conversion efficiency by about 20%, allowing the development of lower-temperature resources.
- Field test heat exchanger tube coatings that reduce fouling rates by 30%.
- Complete field tests of gas monitors that reduce plant operating and maintenance costs by over 5%.

FY 2001 - 2004 Planned Accomplishments

- Following the conclusion of 3-D seismic studies and development of borehole electromagnetic imaging technology to identify fractured geothermal reservoirs, exploration data from seismic, electromagnetic, geochemical, and geological investigations integrate into a comprehensive dynamic model of the geothermal reservoir.
- Building on the wireless data telemetry technology Sandia licensed to Baker Hughes in 1998, complete the high-speed diagnostics-while-drilling (DWD) system. This will greatly improve drilling operations while providing an additional 20% reduction in well costs.
- Conduct initial testing and evaluation of the Geothermal Advanced Drilling System combining state-of-the-art components.
- Incorporate the analytical tools developed with the completion of the improved injection technology for sustainable field operation in FY-2000 into an innovative technique for numerical modeling of geothermal reservoirs.
- Create an Enhanced Geothermal System at a geothermal field with an industrial partner.

- Following commercial-scale testing of the Kalina Cycle (ammonia-water system), initiate testing of advanced binary power plants using mixed working-fluid cycles.
- Initiate new cost-shared direct use applications systems to evaluate innovations that reduce operating and maintenance costs.

FY 2000 Program Shifts

- The Enhanced Geothermal Systems (EGS) initiative will focus on extending the productivity and lifetime of geothermal reservoirs through rock fracturing and stimulation techniques. In addition to extending the lifetime of existing geothermal fields, EGS technology will expand the U.S. geothermal resources available for utilization.
- The new Geothermal Advanced Drilling System (GADS) initiative is a systems approach to reducing drilling costs for drilling in deep, hot, hard rock environments. In conjunction with EGS, GADS will give economic access to geothermal resources contained in rocks at great depth.
- The new Modular Power Systems initiative will begin development of a small-scale power module for the production of electricity at distributed or off-grid sites. Many small-scale power modules eventually will be installed worldwide as a result of this initiative.

Program Completion

The Strategic Plan for the Geothermal Energy Program is based on the assumption that, given the necessary resources, the Program will be completed in 2010. Certain elements are expected to end sooner, such as Geothermal Heat Pump Deployment (2000). The Program goals and their associated objectives as specified in the Strategic Plan will be achieved in partnership with industry and other stakeholders to create technology that reduces the cost and risk of producing all forms of geothermal energy.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Geothermal Electric R&D	22,294	22,000	29,500	+7,500	+34.1%
Geothermal Heat Pumps	6,400	6,500	0	-6,500	-100.0%
Total, Geothermal	28,694	28,500	29,500	+1,000	-66.0%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Geothermal Electric R&D			
■ **Reservoir Technology** - The program will perform water injection test at a commercial site at Dixie Valley, develop a suite of chemical tracers for tracing the flow of injected water and use field test data to improve reservoir models. Industry is cost sharing the field testing of tracers and reservoir model improvements. These efforts will lead to proper fluid management which will allow a geothermal field to operate in a sustainable mode for over 100 years. Research in support of the proposed Santa Rosa pipeline to The Geysers will be conducted. Initiate the Enhanced Geothermal Systems (EGS) initiative will focus on extending the productivity and lifetime of geothermal reservoirs. The EGS initiative calls for conducting a large-scale stimulation, water injection, and circulation experiment at an operating U.S. geothermal field. With industry cooperation and support in the form of cost sharing, this effort will accelerate the use of EGS in the U.S. by at least five years and restore the U.S. as a world leader in EGS technology development. The funding is appropriate to support joint DOE/industry R&D critical to sustaining improvements in maintaining the U.S. technology.	4,387	5,500	8,000
■ **Exploration** - Finding and assessing a viable resource is the stage of geothermal development with the highest risk. Greater effectiveness in locating geothermal resources will reduce the number of non-productive wells that are drilled. The program will evaluate through field testing various 3D seismic exploration strategies. Neural networks for integrating geophysical methods will be evaluated, followed by smart systems using the best neural network. The funding is appropriate as it directly supports the Geothermal Strategic Plan goal of developing future geothermal resources.	5,600	5,500	7,000
■ **Drilling Technology** - The drilling of wells constitute up to one half of the cost of a geothermal power plant. The program will complete the testing of improved PDC bits, unshielded high-temperature logging tools, and a high-temperature casing inspection tool. A successor to the National Advanced			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Drilling and Excavation Technologies (NADET) program, the Geothermal Advanced Drilling System will be initiated in order to insure that drilling costs that increase linearly with depth as opposed to the exponential increases that exist today. Thus, the huge geothermal resources contained in rocks at great depth will become economically accessible. One element of the Geothermal Advanced Drilling System is a high speed data link that will transmit a variety of real-time drilling data to the surface for decision making during operations. This data stream will be of great benefit to drillers and will allow faster, cheaper drilling. About 50% of the cost of the high-speed datalink system will be provided by major private sector partners and most other projects have same level of cost-sharing by industry partners. Based on DOE's interactions with the U.S. geothermal industry, the funding is appropriate for the high priority of reducing drilling costs.	6,900	5,000	7,500
■ **Energy Conversion Technology** - The Kalina Cycle, a new plant design for more efficient and cost effective electrical generation will be tested in partnership with Exergy, Inc. Construction of this demonstration of advanced heat recuperation technology will be completed. The non-Federal share of costs of this demonstration is over 60%. Based on prior technology assessments performed by national laboratories, a cost sharing partner for demonstration of a small-scale geothermal power module will be competitively selected. Modular geothermal power plants offer flexibility in deployment, allowing less risky, incremental development of a geothermal field. Some geothermal fields are located on the fringes of existing power grids where modular, small-scale geothermal power plants can maintain voltage levels and provide other valuable power quality assistance. Modular geothermal power plants can also support mini-grids in remote applications. The funding is appropriate for continuation of this important R&D and achieving the goals in the Geothermal Strategic Plan.	5,119	6,000	7,000
■ **Ocean R&D** - Completed tests of energy conversion system at Keahole Point, Hawaii.	288	0	0
Total, Geothermal Electric R&D.	22,294	22,000	29,500

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Geothermal Heat Pumps			
■ In response to a consensus of industry stakeholders, the program will penetrate 2-4 additional target markets each with several thousand GHP installations annually. The non-Federal share of costs of these demonstrations will be over 66%. In partnership with DOE's Federal Energy Management Program, Federal agencies will install 10,000 GHPs at no capital cost through Super Energy Savings Performance Contracts. No activities are planned beyond FY 2000.	6,400	6,500	0
Total, Geothermal.	28,694	28,500	29,500

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Geothermal Electric R&D	
■ The increase supports new initiatives in reservoir technology, advanced drilling and energy conversion designed to allow the U.S. to retain its leadership in technology development while making the best economic use of the large geothermal energy resource.	+7,500
Geothermal Heat Pumps	
■ The decrease in funds reflects the decision to withdraw Federal support and let market forces determine the extent to which this technology succeeds.	-6,500
Total Funding Change, Geothermal.	+1,000

Hydrogen Research

Mission Supporting Goals and Objectives

Program Mission

The mission of the Hydrogen Research and Development program is to enhance and support the development of cost competitive hydrogen production and storage technologies, and provide for integrated systems. Hydrogen can serve as an energy carrier that can reduce adverse environmental impacts, improve national security, by facilitating the penetration of renewable energy resources into the U.S. energy mix.

Program Goals and Objectives

Over the next five years, hydrogen is expected to make a significant penetration in several niche markets as concerns increase for energy security and global climate change. The Proton Exchange Membrane (PEM) fuel cell is the primary technology that will advance hydrogen into these niche markets and eventually into more mainstream applications such as large-scale electricity generation and transportation. The Hydrogen Program will cost-share the introduction of new hydrogen-based technologies to: provide distributed electrical generation; reduce the use of petroleum; increase the use of domestic energy resources; and increase the efficiency of, and reduce emissions from, existing fossil energy systems.

Development of critical technologies to lower the cost of hydrogen production, storage and utilization is vital for the introduction of hydrogen into the energy infrastructure. The Program facilitates the introduction of these technologies in high priority areas -- such as renewable/hydrogen electric generation systems, refueling stations for hydrogen vehicles and electricity for Native American villages and other remote locations. These crucial activities reduce dependency on expensive oil products, promote rural electrification, and economic development, and use grid-independent systems, while reducing NOx, SOx, and CO_2 emissions. These areas are goals outlined in the DOE Strategic Plan: (1) Objective 1, Strategy 4 to develop alternative transportation fuels and more efficient vehicles that can reduce year 2010 projected oil imports; (2) Objective 2, Strategy 3 to develop renewable energy technologies and supporting policies capable of doubling non-hydroelectric renewable energy generating capacity; and (3) Objective 3, Strategy 2 to increase the efficiency and productivity of energy use by 2010, limit energy related releases of NOx, SOx, and CO_2, and particulates, and other wastes by as much as 5 percent relative to projected emissions.

The Core Research and Development effort will:

- Achieve hydrogen production costs of $12.00 - $15.00 per million Btu for pressurized hydrogen from natural gas and biomass when systems are produced in quantity;
- Develop safe, low-cost, hydrogen storage technology for on-board a vehicle to achieve a 350 mile range; and safely store hydrogen on vehicles to achieve 350 mile range; and
- Develop a reversible fuel cell at <$600/kW when systems are produced in quantity.

The Technology Validation effort will:

- Install a wind/reversible fuel cell in a remote Arctic location;

- Install distributed refueling stations that demonstrate co-production of hydrogen and electricity from natural gas. The hydrogen will be less than $1.20 per gallon equivalent and an electricity production cost less than $0.06 per kWh when systems are produced in quantity; and
- Install a liquid-fueled PEM fuel cell for remote and village power applications.

Strategic Approach

The Hydrogen Program utilizes the core competency of the National Laboratories, universities, and industry to develop and demonstrate the processes and technologies needed to produce, store, transport, and utilize hydrogen safely in various applications. Reduction of greenhouse gases is a major emphasis of the Hydrogen Program, consistent with the objectives of the DOE Strategic Plan. Major initiatives in the Program to meet these objectives include: (1) the transitional use of natural gas as the feedstock for the production of hydrogen while renewable resource technology is under development; (2) the introduction of PEM fuel cells for cogeneration systems integrated with natural gas reformers; (3) the development of codes and standards to ensure the safest technologies are produced and ready for market penetration; and (4) the use of domestic resources to produce hydrogen as a future energy carrier.

To achieve its mission, the hydrogen program has four strategies: (1) expand the use of hydrogen in the near-term by working with industry, including hydrogen producers, to improve efficiency, lower the emissions, and lower the cost of technologies that produce hydrogen from natural gas and to introduce renewable-based production options; (2) work with fuel cell manufacturers to develop hydrogen-based electricity storage and generation systems that will enhance the introduction and penetration of distributed, renewable-based utility systems; (3) coordinate with the Department of Defense and DOE's Office of Transportation Technologies to demonstrate safe and cost-effective fueling systems for hydrogen vehicles in urban non-attainment areas and to provide onboard hydrogen storage systems; and (4) work with the National Laboratories to lower the cost of technologies that produce hydrogen directly from sunlight and water.

The FY 2000 request continues to implement the program outlined in the Department's Hydrogen Multiyear Plan and recommended by the Hydrogen Technical Advisory Panel (HTAP) report, including increased collaboration with the Office of Fossil Energy (FE) and the Office of Science (formerly the Office of Energy Research). The Program has already initiated one co-funded project with FE in advanced reforming for the production of Asyngas,@ a blend of carbon monoxide and hydrogen. The syngas is used by the AGas to Liquids Program@ to produce new liquid fuels while the Hydrogen Program is using the technology for distributed production systems at refueling centers. The Hydrogen Program is pursuing other technologies, such as producing hydrogen from low rank coal with integrated carbon sequestration, or producing high-value carbon products in cooperation with FE=s Vision 21 plan.

The market conversion to widespread hydrogen is a long-term option which requires the development and introduction of a number of critical technologies. These include low-cost, high-density storage systems, low-cost PEM fuel cells, and small load-following reformers for distributed production systems. This technology has received a major boost due to three industry-led developments: the Daimler Benz and Ballard joint venture to produce fuel cell vehicles by 2004; the Plug Power joint venture to produce hundreds of natural gas reformer/ PEM fuel cell systems for home cogeneration; and General Public Utilities= joint venture with Ballard to produce 250 kWe PEM fuel cells by 2002. These activities are

providing market pull to other manufacturers of hydrogen energy systems. Increased hydrogen activity will open up markets for renewable technologies, such as wind and photovoltaics, by providing energy storage options.

Program Benefits

Metric	FY 2000	FY 2010	FY 2020
Primary Energy Displaced (Quads)	0.00	0.09	0.60
Energy Savings ($ Billions)	0.00	0.10	1.63
Carbon Displaced (MMTCE)	0.07	1.35	9.31

The estimated benefits are based on a contribution of hydrogen fuel cells to the Nation=s future electricity generation mix. Hydrogen fuel cells are expected to account for 36 GW, a 4.2% share of the projected U.S. total power by the year 2020. If this Program is implemented as proposed, the Renewable Energy Penetration Model projects installation of an additional 21 GW of fuel cells between 2016 - 2020, which equates to 27% of all new electric capacity in the U.S. This 57 GW of electrical generation can provide enough power to support a city of 10 million homes and businesses.

Performance Measures

FY 2000 Performance Measures

- Demonstrate a 3-fold increase in hydrogen production from biologically catalyzed process.
- Demonstrate 600 mAmps per square centimeter at 0.5 volts in a low-cost manufactured stainless steel PEM fuel cell configuration.

FY 2001-2006 Performance Measures

- Demonstrate carbon dioxide free production of hydrogen using a plasmatron (electric torch) at a scale of 30 kW.
- Demonstrate Ion Transport Membrane technology at 10kW for applications at a distributed production facility.
- Construct a pilot plant for fabrication of carbon nanostructures for 4 percent hydrogen by weight storage.

Significant Accomplishments and Program Shifts

Pre-FY 1998 Accomplishments

Over the last three years, the Hydrogen Program has had significant programmatic and technical accomplishments towards meeting its goals. These include:

- Researchers have been granted over 18 patents.
- Four researchers have been named Distinguished Scientists, by the American Institute of Chemical Engineers, the American Chemical Society, the Columbus Award, and the President=s Award.
- NREL researchers have demonstrated: (1) a triple junction semiconductor for splitting water with a measured solar to hydrogen efficiency greater than 12.5%. (Prior to this the highest recorded efficiency was 7.3%.) (2) A biologically catalyzed water gas-shift catalysis process with over 90% conversion of carbon monoxide to hydrogen was demonstrated.

FY 1998 Accomplishments

- Completed Technology Roadmaps for the Core R&D Program, Technology Validation, and Analysis and Outreach activities that define the goals and objectives to be accomplished over the next five years. This activity is a key part of a deliverable for the Report to Congress due in January 1999.
- At the University of Hawaii, a state-of-the-art bioreactor was installed in a collaborative project with the Japanese and Italians to produce hydrogen using microalgae.
- An innovative PEM fuel cell constructed of stainless steel was tested at atmospheric pressure and temperature for over 2000 hours without any degradation of performance.
- Completed the prototype of a low-cost thick film solid state hydrogen sensor.

FY 1999 Planned Accomplishments

- Initiate a resource assessment for the Montana Trade Port Authority for the construction of a solid waste hydrogen fuel cell manufacturing facility.
- Successfully operate a 50kW renewable hydrogen refueling station at Sunline Transit in the City of Palm Springs.
- Issue a solicitation for the construction of a refueling station to be built in Nevada to service Las Vegas.
- Operate a cryogenic gas tank for vehicle storage to support a 400 mile range configuration for 100 refilling cycles.
- Complete scale-up of Sorbent Enhanced Reformer concept and perform economic analysis of system used for central generation of hydrogen.
- Demonstrate a photochromic method for rapidly identifying algae that will produce hydrogen from water, without being inhibited by by-product hydrogen.
- Three Alaska Remote Power activities will be initiated: an integrated wind/reversible fuel cell system for a remote village to be tested at the University of Alaska; an arctic lab at the University of Alaska; and a project to be initiated on a fuel cell power system (known as autothermal reformer) that uses diesel oil to produce hydrogen for a residential fuel cell.

Complete the feasibility study on the Montana Trade Port Authority.

FY 2000 Planned Accomplishments

A new metal hydride complex (alanates) has been developed with a hydrogen capacity in excess of 5% by weight and energy storage efficiency greater than 74% and will be demonstrated in a system.

Successfully operate a reversible fuel cell with 60% round-trip efficiency in a remote Arctic application.

Operate a quick-fill refueling station to be built in Nevada to service Las Vegas shuttle buses, and Nevada Test Site and Nellie Air Force Base vehicles.

Achieve long-term stability of catalysts for carbon monoxide.

Demonstrate a 3-fold increase in hydrogen production at 15 atmospheres using photosynthetic bacteria for the water gas shift reaction.

Demonstrate over 90% absorption of carbon dioxide in a dual bed Sorbent enhanced reformer reactor used for hydrogen production.

Demonstrate a solar-to-hydrogen efficiency greater than 12% for a III-V tandem cell and greater than 8% for amorphous silicon photoelectrochemical systems.

A lightweight tank will be fabricated to validate a new class of magnesium-based metal hydrides with 4.5% by weight storage at a dehydriding temperature of 150^{o} C.

Demonstrate improved catalyzed hydride concept.

A solicitation will be issued for innovative ideas, components, and concepts for compression and storage systems for both stationary and mobile applications.

Demonstrate a fiber optic sensor using tungsten oxide to indicate hydrogen leaks in a vehicular application.

Demonstrate PEM fuel cell performance of 600 mAmps per square centimeter at .5 volts for a metal separator plate configuration.

FY 2001 - 2004 Planned Accomplishments

Successfully operate for three months the carbon dioxide free production of hydrogen using a plasmatron (electrical torch) at a scale of 30kWe.

Demonstrate a 1kWe solid oxide fuel cell with integrated natural gas reformer for one year.

Operate a single-stage 150 square meter photobiological reactor to produce hydrogen from water using oxygen tolerant mutants.

Successfully deploy and operate small liquid fueled reformer/PEM fuel cells in an arctic environment.

Install advanced refueling stations for fleets of vehicles that demonstrate the ability to provide hydrogen at $1.00/gallon equivalent and electric power at $0.05/kWh for mass-produced systems.

Successfully operate a pilot plant for a biological water gas shift catalyst using reformed biomass for one year.

- # Demonstrate 8% efficiency for hydrogen production and greater than 3,000 hours operation in an outdoor photoelectrochemical system using amorphous silicon.
- # Successfully operate for one year an advanced chemical hydride fuel refueling station to service fleets of hydrogen vehicles. Install advanced chemical hydride storage tanks on vehicles.

Program Completion

The program will be completed in FY 2020 after the following strategic objectives have been achieved:

- # FY 2002 - Non-energy (capital and operating) cost of electricity from hydrogen-based storage systems will be lowered to $0.05/kWh. Plant cost of renewable hydrogen produced at atmospheric pressure, from sunlight and water not using electrolysis will be reduced to$9.00-$15.00/MMBtu. The cost of hydrogen delivered to a vehicle at pressure will be reduced to $12.00-$15.00/MMBtu when systems are produced in quantity.
- # FY 2008 - Hydrogen use increases from 0.3Quad/yr (as a chemical feedstock to produce reformulated gasoline), to 0.4Quad/yr (as a transportation fuel and chemical feedstock).
- # FY 2010 - Deployment of new hydrogen production technologies to convert natural gas for fuel cell applications will reduce emissions by: 61,000 tons per year NOx, 1,000,000 tons per year CO, and 46 million tons per year CO_2. Hydrogen-based systems will begin to displace fossil fuels in utility, building, and vehicle applications leading to 0.1Quad/yr .
- # FY 2020^{+} - Hydrogen-based systems will begin to displace fossil fuels in utility, building, and vehicle applications leading to 1 Quad use.
- # Renewable energy based hydrogen production will contribute the equivalent of 10Quad/yr in the primary energy market.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Core Research and Development.....	6,975	9,088	14,100	+5,012	+55.1%
Technology Validation	6,361	10,993	11,420	+427	+3.9%
Analysis and Outreach.....	2,470	2,169	2,480	+311	+14.3%
Total, Hydrogen Research.....	15,806	22,250	28,000	+5,750	+25.8%

Detailed Program Justification

(dollars in thousands)

FY 1998	FY 1999	FY 2000

Core Research & Development

# **Thermal Processes -** Support will be provided for installation and operation of two process development units to demonstrate production of hydrogen, one using biomass and one using natural gas. Performance characteristics will be determined. Research will be supported for fabrication and operation of a 6kW integrated plasma reformer, for operation and performance characterization of a supercritical biomass gasification reactor, development of a liquid fueled reformer, and for the manufacture of ion transport membrane reactor technology in a collaboration with the Office of Fossil Energy. The funding level is appropriate and was derived through past experience and evaluation by experts in a peer review of on-going efforts. This is linked to the goals and objectives outlined in the R&D Technology roadmap.....	2,957	4,559	5,880
# **Photolytic Processes** - Research will be supported to genetically engineer marine algae to split sea water to hydrogen and oxygen, for fabrication of a modular photo electrochemical production cell, lifetime testing of high efficiency coated cells, developing higher efficient multijunction amorphus silicon semi-conductors, and the operation and design of a process development unit to biochemically react waste carbon monoxide to produce hydrogen at near 100% efficiency using an engineered strain of microbes. The Hydrogen Program in conjunction with the National Science Foundation, conducted a Peer Review of the renewable-based production technologies. This information provided the most important tool to determine if the funding levels requested were appropriate. Through analysis, the experts determined the funding level was appropriate to meet the goals outlined in the R&D Technology roadmap.	1,780	1,700	2,630
# **Storage** - Develop technology for the continuous production of carbon based hydrogen storage materials including nanotubes, for fabrication of four lightweight metal hydride storage modules, for fabrication of an integrated reformer into a vehicle, and for the validation of advanced pressurized gas storage technologies. The funding level was determined through project reviews with program participants to provide on-board hydrogen	1,848	1,829	3,090

	storage systems for vehicles and for distributed generated systems to support the collaboration with the Office of Transportation Technologies.			
#	**Utilization -** Develop end-use technologies, sensors, and other processes that can effectively use the system advantages of converting chemical energy to electrical energy. The program co-funds and co-manages these projects in collaboration with the DOE Office of Transportation Technologies**:** Fuel Cell Program. The following technologies are included: PEM fuel cell and reversible fuel cell technologies, internal combustion engines, hydrogen detectors and measurement sensors. Support will be provided for the prototype design, fabrication and field testing of a newly developed solid-state hydrogen leak detectors; for development of a 50kW scaleable modular PEM fuel cell readily adaptable to inexpensive mass production; and for fabrication of a 25kW fuel cell for integration into a small stationary power system. The funding level is based on extensive experience with the development of PEM fuel cells and sensors to meet key programmatic milestones for demonstrating safe end-use systems	390	1,000	2,500
	Total Core Research and Development.....	6,975	9,088	14,100
	Technology Validation			
#	Install and demonstrate several solar and wind/reversible hydrogen generation and storage fuel cell systems and confirmation of the economic viability of these systems for remote and on-grid utility applications.	1,500	2,524	2,765
#	Install and demonstrate liquid fuel cell (PEM) systems for use in a remote village in an arctic environment.	0	2,823	3,030
#	Demonstrate technologies for hydrogen infrastructure for fueling of hydrogen vehicles. The later activity will include work initiated in FY 1999 for a natural gas based refueling station to be located in Nevada to service a fleet of vehicles with advanced hydride and cryo-pressure tanks installed.	1,261	2,675	5,625
#	Broad based solicitation for storage systems on vehicles.	600	0	0
#	Initiated Russian American Fuel Cell Consortium Projects.	3,000	0	0
#	Fabricate high-pressure hydrogen storage tanks for vehicles.	0	2,971	0

Complete the construction of one joint-venture renewable hydrogen venture.....			
The level of funding requested for technology validation activities was determined by analysis of individual component technologies to provide a hydrogen fueling station, on-board hydrogen storage for vehicle validation projects, three PEM fuel cell systems for distributed remote power projects, and a 100kW reversible fuel cell system for an arctic environment. Prior experience and contractor proposals were used in this assessment.			
Total, Technology Validation.	6,361	10,993	11,420

Analysis and Outreach

# Conduct economic analyses and technical assessments for technologies being developed and demonstrated, in addition support will be provided for similar studies on hydrogen systems involving technologies from production to end use, to provide insight into the applications most likely to be commercially viable and identify areas of further needs in R&D and technology validation. Initiate resource assessment in Montana to determine feasibility of a solid waste hydrogen fuel cell manufacturing facility in the community. Continue development of educational materials			
including an interactive CD ROM for middle and high school students, a curriculum module to teach chemistry on the basis of hydrogen and the environmental impact of fuels, and the production of an adult educational film on hydrogen use in energy applications, as well as several topical films.			
The funding level is appropriate as determined by the Secretary=s Hydrogen Technical Advisory Panel and by the Program=s Peer Review Team.	2,470	2,169	2,480
Total, Hydrogen Research.....	15,806	22,250	28,000

Explanation of Funding Changes from FY 1999 to FY 2000

FY 2000 vs. FY 1999 ($000)

Core Research and Development

		FY 2000 vs. FY 1999 ($000)
#	**Thermal Processes** - The Program will fully fund two thermal conversion processes that produce hydrogen from natural gas with a 20-30% increase in efficiency over conventional processes; and one award to integrate the biologically catalyzed water gas shift process to a pyrolysis reactor to verify process performance.	+1,321
#	**Photolytic Processes** - The Program will award multiple cooperative agreements; at least one award to integrate the new strains of algae into a bioreactor system for process development and characterization; one award to scale-up photoelectrochemical processes to characterize the materials performance and engineering requirements.	+930
#	**Storage** - The Program will award at least one project to complete the characterization of the family of new metal hydride materials to reduce the pyrophoric sensitivity of the alloys; and at least one award to assemble carbon absorbents into a laboratory scale storage system for characterization and demonstration.	+1,261
#	**Utilization** - The Program will fund the prototype design, fabrication and field testing of newly developed solid state hydrogen leak detectors; and for fabrication of a 25kW fuel cell for integration into a small stationary power system.	+1,500
	Total, Core Research and Development	+5,012

Technology Validation

#	**Technology Validation** - The program will award cooperative agreements for additional stand-alone power generation systems using proton exchange membrane fuel cells to produce electricity and generate hydrogen.	+427

Analysis and Outreach

#	**Analysis and Outreach** - The program will award a cooperative agreement for the production of an educational video on hydrogen technologies and complete the resource assessment in Montana.	+311
	Total Funding Change, Hydrogen Research and Development Program	+5,750

Hydropower

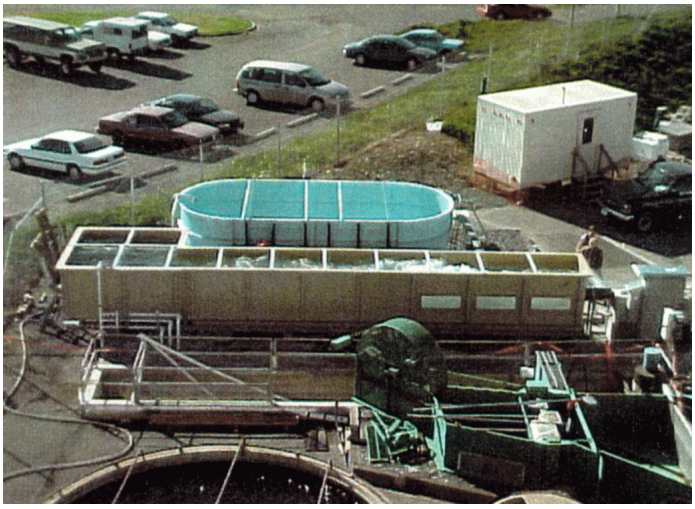
Mission Supporting Goals & Objectives

Program Mission

The mission of the U.S. Department of Energy=s Hydropower Program is to improve the technical, societal, and environmental benefits of hydropower resources by conducting collaborative research and development with industry and other Federal agencies.

Program Goals and Objectives

Working with industry and other Federal agencies, the Hydropower Program=s research and development activities will provide a biological and engineering basis for a new generation of hydropower turbines. Successful development will reduce turbine-induced fish mortality to 2% or less, compared to current levels ranging up to 30% or greater, and maintain dissolved oxygen levels of at least 6 mg/liter, ensuring compliance with water quality standards. This program addresses the goal stated in the Comprehensive National Energy Strategy (CNES) Ato promote energy production and use in ways that respect health and environmental values - improving our health and local, regional and global environmental quality.@ To meet this goal, one of the strategies proposed in the CNES is to Amaintain the viability of existing hydropower sources@. Specifically, CNES states that Athe development of advanced hydropower turbines to repower existing dams has the potential to avoid some of the environmental challenges posed by conventional hydropower plants and extend the life of existing hydropower plants to help preserve their contribution to U.S. energy production.@



Strategic Approach

Hydropower currently generates about 10% of the nation=s electricity. However, existing generation is in jeopardy, due to a combination of real and perceived environmental problems, regulatory complexity and pressures, and changes in energy economics. New hydropower resources are often not being developed for similar reasons. Current hydropower technology, while essentially emission-free, can have undesirable environmental effects such as fish injury and mortality from passage through turbines and the alteration of downstream water quality and quantity. Incorporation of advanced turbine technology could provide estimated capacity improvements of 4,000MW at existing federal facilities, 1,300MW at existing non-Federal facilities requiring relicensing over the next 12 years, and 4,800MW of new capacity.

In FY 2000 the program will complete the proof-of-concept testing of an innovative design selected through a competitive bidding process. Biological performance will be determined and test results

provided to industry. Experiments to establish biological performance criteria will continue, providing biologists and engineers with quantitative data on fish behavior and response in the turbine environment. Final engineering designs for turbines with advanced features to improve dissolved oxygen conditions will begin.

The DOE program is intended to develop hydropower technology with wide applicability. Much of the research presently carried out by Federal hydropower operators, as well as utilities, is site-specific, addresses specific environmental and equipment problems, and has limited general applicability. Moreover, with deregulation utilities are beginning to reduce their research activities, and utility organizations which sponsor R&D are losing membership and cannot maintain these activities at previous levels. Research funded by the few US manufacturers is aimed at minor improvements to the product line, is usually proprietary, and for that reason again lacks general applicability.

Program Benefits

Metric	FY 2000	FY 2010	FY 2020
Primary Energy Displaced (Quads)	0.01	0.08	0.18
Energy Savings ($ Billions)	0.02	0.20	0.53
Carbon Displaced (MMTCE)	0.15	1.35	3.00

Performance Measures

FY 2000 Performance Measures

- Proof-of-concept testing of advanced turbine conceptual design completed in FY 2000; biological performance predictions verified and test results provided to industry.

FY 2001-2006 Performance Measures

- Completion of full-scale advanced turbine prototype testing in FY 2005, successfully demonstrating the capability of maintaining dissolved oxygen levels of 6 mg/liter.

Significant Accomplishments and Program Shifts

Pre-FY 1998 Accomplishments

- Completed conceptual designs for advanced turbines.

FY 1998 Accomplishments

- Hydropower resource assessments completed for all 50 states, providing a more accurate estimate of viable undeveloped hydropower potential (~30,000MW).
- Conducted laboratory biological studies of the effects of shear stresses on turbine-passed fish.

FY 1999 Planned Accomplishments

- Begin proof-of-concept testing of advanced turbine conceptual design to verify predicted biological performance.

Begin design of instrumentation for real-time visualization and accurate simulation of fish passing through turbines

FY 2000 Planned Accomplishments

Complete proof-of-concept testing of conceptual turbine design.

FY 2001-2004 Planned Accomplishments

Complete experiments to establish biologically-based performance criteria for advanced turbine design.

Complete final engineering designs for turbines with advanced dissolved oxygen features; begin model fabrication and testing.

Complete model testing of turbines with advanced dissolved oxygen features.

Complete design of fish passage visualization/simulation instrumentation.

Complete final engineering designs for turbines with advanced fish passage features.

Complete model testing of turbine designs with advanced fish passage features.

Program Completion

Program completion is envisioned for the 2008 time frame assuming levels of funding sufficient to achieve the successful demonstration of biological performance of advanced hydropower technology.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Advanced Turbine Research and Development	729	3,250	7,000	+3,750	+115.4%
Total, Hydropower	729	3,250	7,000	+3,750	+115.4%

Detailed Program Justification

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
Advanced Turbine Research & Development			
# Complete the pilot-scale laboratory proof-of-concept testing of the conceptual design to verify biological criteria and predicted biological performance using live fish. The funding level is based on previous turbine research efforts and anticipated laboratory in-house costs.....	0	2,170	2,500
# Complete the biological experiments and instrumentation development to establish biologically-based performance criteria required for advanced turbine development. The funding level is based on account experience the funding level requested is considered adequate.....	729	1,080	2,500
# Initiate competitively-selected cost-shared engineering design of turbines with advanced dissolved oxygen features. As the engineering design phase is a pre-commercialization activity, cost-sharing of at least 20% will be a requirement in the competitive solicitation. Experience with the competitive solicitation in the conceptual design phase demonstrated the limited ability of industry to cost-share in pre-commercialization activities. The full-scale prototype testing phase planned for FY 2002 will require at least 50% cost-sharing. It is anticipated that turbine manufacturers responding to a solicitation for this phase will be teamed with a developer in order to achieve this level of cost-sharing. The funding level is based on previous experience, anticipated in-house laboratory efforts and expected level of cost-sharing.....	0	0	2,000
Total, Hydropower.	729	3,250	7,000

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Advanced Turbine Research & Development	
# Completion of proof-of-concept testing begun in FY 1999.	+300
# Completion of biological experiments and continued development of turbine passage visualization/simulation instrumentation.	+1,420
# Engineering design phase of the dissolved-oxygen turbine research and development which is aimed at improving dissolved oxygen concentrations in discharged water to at least 6mg/liter.	+2,000
Total Funding Change, Hydropower.	+3,750

Renewable Indian Energy Resources Program

Mission Supporting Goals and Objectives

The FY 1998 and FY 1999 Energy and Water Development Appropriations Report language for Solar and Renewable Energy designated funding for supporting the construction of hydropower and related projects under the Renewable Indian Energy Resource. No funding is requested for any additional activities in FY 2000. Instead, DOE proposes to integrate this program's activities with that of the Federal Buildings/Remote Power line item and create a single, competitive-based, geographically and technologically diverse competitive solicitation program addressing American Indian energy needs. (This program would fall under the Solar Program Support line item).

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Renewable Indian Energy Resources	3,939	4,779	0	-4,779	-100%
Total, Renewable Indian Energy Resources .	3,939	4,779	0	-4,779	-100%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Renewable Indian Energy Resources Program			
■ Eyak Native Corporation Power Creek Hydroelectric Project: Incremental funding was awarded on this 6-mw project, located near Cordova, AK; start-up estimated for March 1999.	1,939	1,243	0
■ Old Harbor Hydroelectric Project: A grant was awarded for project construction of this 335-kW project on Kodiak Island, AK.	800	383	0
■ Upper Lynn Canal Regional Intertie: A grant was awarded for project construction of this 35-Kilovolt submarine cable.	1,000	123	0
■ Scammon Bay Hydroelectric Feasibility Studies: A grant was awarded to conduct feasibility studies for hydropower development.	100	15	0
■ Contruction of Pyramid Creek Hydroelectric Project (600 kW, located on Unalaska Island, AK.	0	1,000	0
■ Contruction of Sitka Diesel Backup System.	0	1,000	0

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
■ Competitively award Native American solicitation for off-grid and grid compatible projects on Native lands.	0	1,000	0
■ DOE monitoring and technical assistance.	100	15	0
Total, Renewable Indian Energy Resources Program.	3,939	4,779	0

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Renewable Indian Energy Resources Program	
■ No funding is requested for any additional activities in FY 2000. Instead, DOE proposes to integrate this program's activities with that of the Federal Buildings/Remote Power line item and create a single, competitive-based, geographically and technologically diverse competitive solicitation program addressing American Indian energy needs. (This program would fall under the Solar Program Support line item).	-4,779
Total Funding Change, Renewable Indian Energy Resources Program	-4,779

Electric Energy Systems and Storage

Mission Supporting Goals and Objective

Program Mission

Transmission Reliability - The mission of the Transmission Reliability Program is to develop technologies and policy options that will maintain and improve the reliability of the nation's electricity delivery system during the transition to competitive power markets.

High Temperature Superconducting R&D - The Department leads the national effort to capture the energy savings potential of superconductivity - the ability of certain materials to be high capacity carriers of electricity without having the resistance losses inherent in normal conductors, such as copper. The mission is to perform research that will create the electricity superhighway of the future by dramatically improving the way electricity is generated, delivered and used.

Energy Storage Systems -The Energy Storage Systems (ESS) Program will work in the new electricity marketplace with its increased emphasis on distributed resources and energy services to develop state-of-the-art energy storage technologies.

The mission is to perform research that provides energy storage systems that create increased value for renewable power systems, and enhance power quality, reliability, productivity and efficiency for electricity users and providers in a competitive electricity infrastructure.

Program Goals and Objectives

Transmission Reliability - The goal of the Transmission Reliability Program is to insure an efficient, reliable power delivery system in the U.S. during the electricity industry transition to competitive markets, through development of advanced technologies that allow lowest-cost, efficient power delivery systems, and integration of distributed resources.

The objectives of the program are to insure the reliability and security of the Nation's electric power system, increase utilization of renewable energy sources, enable customer choice in power quality and self-generation options, provide the capability for information flow needed for the efficient operation of competitive markets, enable significant reduction of air emissions, and enable distributed utility options that integrate natural gas and electric power delivery benefits.

The Program will contribute to the goals and objectives of the Comprehensive National Energy Strategy by supporting competitive and efficient electric systems; ensuring energy system reliability, flexibility, and emergency response capability; accelerating the development and market adoption of environmentally friendly technologies; and developing technologies that expand long term energy options.

The program is projected to be five-years in duration and will ensure that research and development for reliable system and competitive markets is maintained until new market and/or regulatory structures are developed that provide the incentives for the private sector to assume this work. To insure that competitive markets are driving technology choices, any hardware development would be at least 50% cost-shared by the private sector, and Federal support for hardware demonstration would be limited to

test and evaluation activities. The Program also provides a Federal electric power system technical capability to support government policy decision-making during this transition. The Program will be reassessed each year to determine the need for Federal involvement depending on the nature and implementation needs of new regulations, and the impact of market forces.

High Temperature Superconducting R&D - The DOE program is accomplishing two major technological goals: solving the difficult problem of manufacturing electrical wires from the family of brittle ceramic superconducting materials, while in parallel, creating designs of super efficient electrical systems such as motors, transmission cables, generators, transformers and current limiters that use these wires. The products will be resistance-free electrical wires that carry 100 times the current of conventional alternatives and the design of advanced systems that have only half the energy losses and are half the size of conventional alternatives of the same power rating.

Superconductivity will bring a more fundamental change to electric power technology than has occurred since electricity use became widespread over a century ago. The potential is for an energy revolution as profound as the impact fiber optics has had on communication. The fiber optic "information superhighway" was constructed by replacing copper wires with a higher capacity alternative. Superconducting provides an "energy superhighway" that greatly improves efficiency and capacity. The economic (several billion dollars per year market by 2020) and energy impacts (offset potential of 40 medium size conventional generation plants in the U.S. alone) are predicted to be huge.

Perhaps the most important aspect of superconductivity is the contribution it can make in deregulating the electric utility industry. Superconducting transmission lines can provide efficient paths for power to flow from generation sites to load centers with minimal visual or environmental impacts. Superconductivity can also provide many cost and reliability advantages such as increased generator stability, system power control and protection from damaging "fault currents" caused by lightening strikes and other accidents.

The High Temperature Superconducting R&D (HTS) program fits uniquely into Goal I of the Comprehensive National Energy Strategy by increasing the efficiency and economic performance of the national energy system while helping to protect the environment and enhance national security. The superconductor in an HTS transformer reduces electricity energy losses to approximately one-eighth of the level of conventional transformers. The electric losses in HTS cables are approximately half those of conventional overhead transmission lines. Note that the electric energy losses on the United States electric grid due to inefficiencies are greater than all the electricity consumed in the continent of Africa. Consequently, High Temperature Superconductivity devices will make a significant contribution toward increasing the efficiency and economic performance of the U.S. electric system.

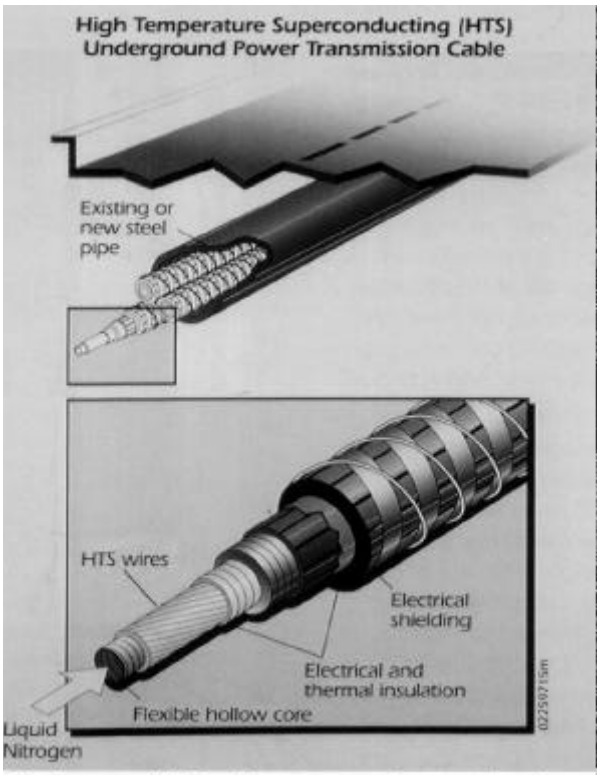
Introduction of HTS technology will affect the environment in two important ways. First, pollution will be reduced. If the entire electric grid and large electric motors were converted to superconductors, CO_2, SOx , and NOx would be reduced by 17,000 thousand metric tons, 300 thousand metric tons and 120 thousand metric tons respectively. The savings in CO_2 are approximately 1% of the total carbon

emissions in the U.S. in 1996. The second area where superconductivity will help improve the environment is by putting unsightly overhead transmission lines underground and reducing the area necessary for power delivery corridors. Finally, superconducting will increase the security of the U.S. electric grid by reducing the exposure of these facilities to acts of vandalism and terrorism.

"**Power Line Makes Use of a Miracle of Physics**

After 87 years of alternating exuberance and disappointments, and a decade after a famous conclave of physicists at which the key to success seemed to be within reach, the world's first superconducting power line is about to become a reality."

NY Times - November 3, 1998 describing the DOE project to provide electricity to downtown Detroit using a superconducting cable.



Underground HTS cables can carry three to five times more current than conventional copper cables.

Energy Storage Systems -The Energy Storage Systems program is working to create energy storage technologies with a cost goal of $700 per/kW and an energy density goal of 5 kWh per square foot by the year 2003.

The Energy Storage Systems program will develop integrated, cost-effective energy storage systems for the three thrust areas of renewables, reliability (including power quality), and productivity. These systems will offer multiple benefits for electricity providers over a wide array of applications, ranting from small scale remote installations to major industrial facilities. Among these benefits are reduced cost to the U.S. economy of power quality and reliability problems; enhanced utility and customer choices in responding to electric industry restructuring; and increased economic value of renewables and distributed resources.

The ESS Program will work with renewable programs and industry partners to develop integrated systems that increase the value of electricity derived from intermittent wind and solar sources by making the power available regardless of when it is generated. Projects will be initiated that will improve the performance of energy storage technologies in hybrid systems. Recent research has projected a world market for photovoltaic hybrids of $4,000,000,000 by the year 2000.

Energy storage systems will improve the reliability and security of the Nation's electricity transmission and distribution system, helping to meet the objectives of ensuring energy system reliability, flexibility, and emergency response capability as outlined in the Comprehensive National Energy Strategy. Transmission and distribution system productivity and efficiency will be enhanced by storage systems that correct the brief power outages and distortions estimated to cost U.S. industry over $100,000,000,000 a year.

Energy storage systems can also provide significant productivity gains for large electricity users and providers, increasing the competitiveness of U.S. industry. The ESS Program will develop systems for distributed siting that offer multiple benefits for the user including avoidance of peak demand charges, reduced equipment failures, from power-quality problems.

Federal involvement through the ESS Program is critical to the long-range development of conventional and emerging storage technologies. These storage technologies are key to increasing the value of DOE's renewable energy programs for both grid-connected and remotely-sited systems. Energy storage systems integrated with distributed resources into the electric distribution systems, provide the customers with energy control options for maintaining system reliability.

Strategic Approach

Transmission Reliability - The Transmission Reliability Program will be implemented through a National laboratory/electric industry partnership to conduct research on the reliability of the Nation's electricity infrastructure. This strategic partnering approach will insure that research and development (R&D) is defined and initiated that meets electric industry needs, and can be transition for further development or deployment by the industry. The Program will collaborate with industrial and academic partners to develop technologies that promote competitive markets, ensure system reliability (adequacy and security), increase network capacity for large scale, long distance power transfers, and promote integration of distributed resources, including renewable generation and storage. The Program will also examine how market stimuli, and Federal and State regulation combined with the development and application of advanced technologies can be structured to assure incentives for private funding for reliability R&D, and additions of new technologies during and after the transition to competition.

The Transmission Reliability Program focuses on applying advanced computing, sensing, power electronics, communications, and control technologies to provide real time system control for reliable, efficient operation of the Nation's electric power system under both normal and emergency operating conditions. These fundamental technologies will be developed into advanced systems applications under the Power Systems Reliability and Distributed Power activities.

Power Systems Reliability will develop control and information systems to monitor and control the power system in real time, and advanced power electronics to accomplis fast, high-power switching under real time system control. Real time system control will apply next generation hardware, and develop advanced power system algorithms which will allow operators to measure the status of the system in real time, thereby allowing maximum integration of advanced technologies into the power system to ensure system reliability, save capital costs by more fully utilizing existing utility assets, and enable competitive markets. Advanced power electronics will adapt existing high-efficiency, low-cost power converter designs for both transmission and distribution system control equipment. This activity will also develop advanced switching devices materials such as silicon carbide, which result in significantly higher capacity, lower cost, and lower loss power conversion equipment than today's power converters provide.

Distributed Power supports development of technologies, and removal of barriers to enable the integration of distributed generation and storage into the electric and natural gas systems. Distributed technologies include renewable resources, fuel cells, microturbines, battery and flywheel storage, and direct load control. Integration of these technologies offers environmental and economic benefits, and

extends competition to the retail customer level. To enable successful integration of distributed resources into the distribution system, the program will address technical, regulatory, and institutional issues. The program will develop technology solutions to allow safe and reliable distributed power system operation that provides both local and transmission-level benefits. In addition, the Federal government will address technical and regulatory barriers that are common to local electricity distributors, and facilitate work with State and local governments to address other institutional barriers.

Distributed power supports strategic research, systems integration, and institutional issue activities. Strategic Research activity will develop advanced system operational concepts for the integration of small, modular generation and storage technologies into the distribution system. System integration issues, including safety, reliability, power quality, interconnection, and environmental issues related to distributed generation and storage, will be identified through modeling and other engineering analyses, case studies and hardware system integration testing and demonstration. The Institutional Issues activity will identify and assess the impacts of current practices, planning methodologies, power systems engineering training, policies, regulations, ownership structures, and other institutional issues on distributed power applications.

High Temperature Superconducting R&D - To accomplish its mission, the High Temperature Superconducting (HTS) program has mobilized the resources of U.S. industry, national laboratories and universities in a high-risk, parallel development approach: research on the underlying technology, superconducting wires, is being done at the same time applications systems are being designed. This approach will effectively reduce the time to introduction of full-scale systems by a decade or more. A strategic alignment is followed in the program structure, with two industry-led initiative elements and a government lead research element.

The very successful Superconductivity Partnership Initiative (SPI) element supports aggressive industry-lead projects to design advanced electrical applications. SPI projects include generators, transformers, motors, transmission cables, current controllers, flywheel energy systems and magnetic separation systems. A unique SPI feature is that each project involves vertically integrated teams (typically including an electric utility, a system manufacturer and a superconducting wire supplier as well as one or more national laboratories). This vertical integration has proven a powerful way to include customer focus and leverage resources.

The industry-led Second Generation Wire Initiative is exploiting breakthroughs at Los Alamos and Oak Ridge National laboratories that promise unprecedented current-carrying capacity in high-temperature superconducting wires. These breakthroughs, which made headlines worldwide, will allow long wire lengths to behave as a single crystal, thus eliminating internal barriers to current flow that may limit the use of wires now being manufactured. Several industry teams are now working with the national laboratories to scale up the new discoveries.

The Strategic Research program element provides the underlying knowledge base needed for the success of the above industry-led projects. The Second Generation Wire Initiative evolved from five years of strategic research that achieved world record performance breakthroughs in short wire samples. Strategic Research will continue on wire processing as well as exploratory research on innovative systems. In addition, research and analysis will be conducted on issues associated with integration of superconducting systems into an increasingly competitive and restructured industry framework.

Energy Storage Systems - The ESS program works with a diverse group of partners to met end user needs. The Program cooperates extensively with electricity users and providers, equipment manufacturers, system integrators, academic and research organizations. This cooperation helps identify merging trends, and supports development of energy storage systems that will play a vital role in a restructured electricity marketplace. Collaboration with industry partners also allows the ESS Program to leverage resources through cost-shared agreements. In FY 1998, the Program received over $1,600,000 in cos-sharing commitments from its industry partners.

The following projects supported by the Program and its partners will contribute to an increase in new storage technology, and save U.S. consumers billions of dollars in energy-related costs: 1) development and testing of factory-integrated PV/storage systems as part of the Renewable Generation and Storage (RGS) project. The RGS project is a major component of the Storage 2000 Initiative, a joint DOE/industry initiative to accelerate technology development for emerging needs in a restructured electricity marketplace; 2) design of a storage-based power quality system to enhance the reliability and security of the Nation's electricity transmission and distribution system in the restructured electricity marketplace; 3) completion of the Mobile PQ 2000 project with the demonstration of a transportable power quality system by an ESS partner; 4) testing of the Advanced Battery Energy Storage System (ABESS), a transportable, modular zinc/bromine battery system that will increase productivity and efficiency for end users; and 5) development of critical storage components such as power conversion systems and controls in a cost-shared program with industry.

Program Benefits

Transmission Reliability

Metric	FY 2000	FY 2010	FY 2020
Primary Energy Displaced (Quads)	0.02	0.12	0.13
Energy Cost Savings ($ Billions)	0.00	0.00	0.00
Carbon Displaced (MMTCE)	0.50	2.00	3.00

Using real time control and information systems along with fast, power electronic switching, power systems will quickly evolve that require less conventional power transmission equipment and less reserve generation capacity, while maintaining overall reliability. These systems will allow energy savings and air emissions reductions from less run-time of standby fossil-fired generation, and capital savings through greater utilization of existing system facilities. The Program also performs a vital Federal role by enabling system benefits and competitive wholesale and retail markets through maximum integration of other DOE-developed technologies such as renewable energy resources, energy storage, superconducting equipment, and fuel cells.

High Temperature Superconducting R&D

Metric	FY 2000	FY 2010	FY 2020
Primary Energy Displaced (Quads)	0.00	0.00	0.01
Energy Cost Savings ($ Billions)	0.00	0.24	1.03
Carbon Displaced (MMTCE)	0.00	0.00	0.14
Direct Electricity Displaced (Billion kWh)	0.00	3.30	14.2
Direct Coal Displaced (Million Short Tons)	0.00	0.72	2.80

Other major benefits are expected in electricity grid capacity and reliability as superconducting technologies are introduced. These benefits may be necessary to meet expected new patterns (and large increases) of electricity flow from producers to consumers as markets are deregulated.

Conservative estimates of gradual technology penetration show that within 20 years over 300,000 households could be supplied by the gains in efficiency due to superconductivity. Efficiency gains possible with an all HTS system represent the electrical needs of 8,000,000 households.

Energy Storage Systems

Metric	FY 2000	FY 2010	FY 2020
Primary Energy Displaced (Quads)	0.00	0.00	0.00
Energy Cost Savings ($ Billions)	0.00	0.00	0.00
Carbon Displaced (MMTCE)	0.01	0.02	0.03

These benefits correspond to powering approximately 1,000 homes in the year FY 2000 with renewable generation and storage systems. Energy displaced and carbon reduction result from enhanced integration of renewable energy resources into the electricity market, and peak load reduction. Improved productivity and electric power reliability resulting from improved power quality account for the non-energy cost savings.

Performance Measures

FY 2000 Performance Measures

Transmission Reliability

- Develop plan for distributed power technologies demonstration test bed.
- Complete draft of uniform interconnection standard for distributed resource technologies.
- Complete action plan for addressing institutional and regulatory barriers for distributed power.

High Temperature Superconducting R&D

- The second generation wire being produced in the program must exceed 100 meters in length and 500 amperes per square millimeter in current density are expected.

- The first-of-a-kind superconducting cable to be installed in downtown Detroit must be flexible enough to be installed under city streets without damage and be able to carry the electrical load efficiently and reliably.
- The superconducting power transformer must carry its rated load efficiently and reliably.

Energy Storage Systems

- Increase the energy available in battery storage systems to 3.0kWh/square foot.

FY 2001 - 2006 Performance Measures

Transmission Reliability

- Develop computer software to simulate real time control algorithms for real time systems control, including reactive power and voltage control.
- Test intelligent distributed control agent to provide control and information for distributed power management.
- Complete Phase I of distributed power system integration tests.
- Test high voltage power electronic converter for power transmission application.
- Test device-grade, high band-gap switching material for power converter at intermediate voltages.

High Temperature Superconducting R&D

- Develop the capability to manufacturer kilometer lengths of high capacity wire (current-carrying ability of 1,000 amperes per square millimeter cross-section) at a potential cost of $0.01/ampere-meter.
- The first-of-a-kind systems installed during this period must show significant improvements over conventional systems in terms of efficiency, capacity and reliability.

Energy Storage Systems

- Reduce the cost of energy storage systems to $700/kW.
- Increase the energy available in energy storage systems to 5.0kWh/square foot.

Significant Accomplishments and Program Shifts

Pre-FY 1998 Accomplishments

Transmission Reliability

- No program established.

High Temperature Superconducting R&D

- Program participants have set most of the world's technological milestones in the last several years, including those for motors (200 horsepower motor tested), cables (50 meter, 3,000 ampere cable began testing), and transformers (1 MVA unit tested). Four R&D 100 awards were won, as well as

the DOE award for Solid State Physics and the Lockheed Martin Corporation's NOVA award for teamwork.

Energy Storage Systems

- In FY 1997, a 1.4 MWh energy storage system was installed on the Annette Island Reserve in southeast Alaska, home to the 1,700-member Metlakatla Indian tribe. The system, built with technical assistance from the ESS Program and charged by hydropower, eliminates continual use of a 3.3 MW diesel engine. In the first eight months of operation, fuel use was reduced by 180,000 gallons, resulting in a cost savings of over $39,000 a month.
- A 3.5 MWh battery energy storage system was installed at a lead battery recycling plant in Vernon, CA. The system supports critical plant loads during power outages to prevent violations of lead emissions standards and has greatly reduced the plant's costly non-compliance fines. The system has provided peak shaving and uninterrupted power since 1996.
- The PQ 2000 energy storage system was installed at an industry site in Homerville, GA. The 1 MW, 10-second, factory-assembled system corrected over 90% of the plant's power quality disruptions during the first six months of operation. In 1997, DOE, AC Battery and other industry partners, received the prestigious R&D 100 award for the PQ 2000 energy storage system.

FY 1998 Accomplishments

Transmission Reliability

- No program established.

High Temperature Superconducting R&D

- Six teams were selected for funding in the Superconductivity Partnership Initiative (SPI) in a free and open competition. The winners proposed to develop near and long term designs for power cables and transformers, a flywheel power system using superconducting bearings, and a magnetic separation system.
- The SPI 3,000 amp transmission cable was completed, and initial scale-up requirements were met for wire processing breakthroughs by the national laboratories.

Energy Storage Systems

- Completed three studies that define the present and future needs of users of RGS systems, and determine the application requirements of the RGS systems that would meet these needs.
- Field tests of the Mobile PQ 2000 power quality storage system were initiated at a utility site.
- Completed assembly and testing of a small-scale test module zinc/bromine battery with four times the energy density of today's lead acid batteries.

Electric and Magnetic Fields

- Completed planned health effects research and exposure assessments leading to a risk assessment by the National Institute of environmental Health Sciences in 1998.

- Conducted and disseminated a risk evaluation by an international panel of experts concerning health effects from exposure to electric and magnetic fields, and document research results.

FY 1999 Planned Accomplishments

Transmission Reliability

- Completed workshops and six studies to identify and define needs for reliability research in a restructured U.S. electricity industry.

High Temperature Superconducting R&D

- The world's first high-field (1.0 Tesla) superconducting magnet will be built that operates a liquid nitrogen temperatures; a facility designed to manufacture continuous lengths of second generation superconducting wire will be built; and the world's largest HTS motor (1,000 horsepower) will be tested at an industrial site.

Energy Storage Systems

- Develop a test bench-scale hybrid storage/generation hardware and control configurations to assess the optimum use of storage in RGS systems under the Storage 2000 Initiative.
- Develop critical storage components such as power conversion systems and controls in a cost-shared program with industry.

Climate Challenge

- Maintain existing partnership agreements to ensure year 2000 pledge reductions of at least 47 million metric tons of carbon equivalent.
- Expand voluntary industry/government collaboration to reduce greenhouse gases by catalyzing a Climate Change forum with over 600 utility partners to exchange lessons-learned on cost-effectively reducing greenhouse gases.

FY 2000 Planned Accomplishments

Transmission Reliability

- Complete multi-year demonstration plan for distributed technologies test bed.
- Complete draft of uniform interconnection standard for distributed generation and storage technologies.
- Identify regulatory and institutional barriers to distributed power, and develop and begin implementation of an action plan to address these.
- Complete models to simulate ancillary services market designs.

High Temperature Superconducting R&D

- A 3-phase superconducting cable will be the world's first to supply power to a manufacturing complex. The cable will be 30.5 meters long, and will carry 1,250 amperes of current at 12,500 volts. The equivalent power would serve a city of 25,000 people. Construction of a research facility for continuous manufacturing of second generation wire will begin.

- An advanced, and environmentally friendly, 10 mega volt amperes power transformer will be the first to provide electrical service to a manufacturing facility. Half the size and more efficient than conventional alternatives, this superconducting transformer also eliminates oil cooling that can cause fire and pollution problems.
- Technology of "second generation" HTS wires will have advanced to 100 meter lengths being manufactured able to transmit 100 amperes through a one millimeter wire cross-section (over 100 times the capacity of conventional wires).

Energy Storage Systems

- Initiate a substation power quality system project with an industry partner; the system will improve the reliability of the Nation's electricity infrastructure.
- Begin the testing phase of Advanced Battery Energy Storage System (ABESS) project; this technology will increase productivity and efficiency for large end users.
- Complete a cost-shared demonstration of a customer-sited storage system with a major utility; this system will provide cost-savings, load management, and controllable reserve margins for energy providers of the future.
- Complete the Transportable Battery energy Storage System (TBESS) project; an ESS partner will then undertake commercialization of the mobile power quality system.

FY 2001 - 2004 Planned Accomplishments

Transmission Reliability

- Complete evaluation of the correlation between satellite-synchronized system measurements and model predictions of known power system events.
- Deliver software to implement real-time data system for reactive power analysis of large systems.
- Complete assessment of intelligent distributed control agents.
- Complete design of distributed power system integration tests to identify safety, power quality, interconnection, and environmental issues related to distributed generation and storage.
- Initiate large scale simulator tests of real time system control aimed at reducing air emissions and increasing system reliability.
- Complete laboratory development of techniques for production of high purity silicon carbide for advanced power electronic switches.
- Complete Phase I distributed power system integration tests.
- Begin tests of advanced high efficiency, high voltage power electronic converters for power transmission applications.

High Temperature Superconducting R&D

- A number of world-class accomplishments will be achieved. A 5,000 horsepower motor will be run under actual operating conditions to complete the SPI motor project; power will be supplied to businesses in a downtown metropolitan area to complete a SPI cable project; an advanced design 10

MW power transformer will be operated at an electric utility substation; and continuous lengths of high performance second generation wire will become available for incorporation into SPI equipment designs.

Energy Storage Systems

- Complete development and testing of several integrated PV/storage systems as part of the RGS project.
- Test the substation power quality system with industry partners.
- Develop improved advanced storage (e.g., flywheels or SMES) components with industry partners designed for power quality and reliability systems.
- Complete the ABESS project; industry will begin commercialization.

Program Completion

Transmission Reliability

This is projected to be a five-year program to ensure that research and development for reliable systems and competitive markets is maintained until new market and/or regulatory structures are developed that provide the incentives for the private sector to assume this work. Continued involvement with electricity industry participants will ensure that his R&D supports technologies that will integrate into, and be adopted under future operational/market scenarios. The program will be reassessed each year to determine the need for Federal involvement depending on the nature and implementation needs of new regulations, and the impact of market forces under both Federal and State regulations.

High Temperature Superconducting R&D

The program supports basic research on wire materials processing and design of first-of-a-kind systems in order that HTS power applications are brought to widespread use in the shortest possible time.

Basic research activities will be completed during FY 2004 - FY 2006 resulting in practical wires from U.S. manufacturers that can achieve 1,000 amperes per square millimeter of cross-sectional area while operating at liquid nitrogen temperatures in a field of 3 Tesla. "Practical wires" imply flexibility, ruggedness, and affordability when produced in sufficient quantity.

Energy Storage Systems

The Energy Storage Program research and development is focused on enhancing the performance and reliability while reducing the cost of energy storage systems for the competitive electric power marketplace. These energy storage technologies include battery, flywheel, superconducting magnetic energy storage (SMES) and high energy density capacitor systems.

Basic development activities will be completed during FY 2004-FY 2006 with the completion of performance evaluations of systems that meet the cost and energy density goals for the Program.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Transmission Reliability	0	3,000	4,000	+1,000	+33%
High Temperature Superconducting R&D	31,579	32,500	31,000	-1,500	-4.6%
Energy Storage Systems	3,839	4,500	6,000	+1,500	+33%
Climate Challenge	0	100	0	-100	0.0%
Electric and Magnetic Fields R&D	7,844	0	0	0	0.0%
Total, Electric Energy Systems and Storage	43,262	40,100	41,000	+1,900	+4.7%

Detailed Program Justification

(dollars in thousands)

FY 1998	FY 1999	FY 2000

Transmission Reliability

- **Power System Reliability** - Develop real-time measurement and control systems to collect and apply power system data in real time to ensure and enhance electric power system security and reliability, reduce air emissions, and enable efficient markets. Investigate incremental modifications to grid system models to take advantage of real time data. Evaluate data requirements and develop models for ancillary services markets. The funding level is considered appropriate as a ramp-up level from the FY 1999 program start, with the projected placement of additional industry cost-shared contracts under the National laboratory/electric industry partnership to support transmission reliability of the electric infrastructure. The program was formulated after electric industry views on the direction, content and priorities of the program were solicited at a workshop with broad industry representation, and through discussions with EPRI at the yearly DOE/EPRI Sustainable Electric Partnership Executive Conference.

  Develop performance and cost models for advanced multi-level inverters for power system applications, and identify applications for simulation tests. Assess state of the development of high band-gap materials for high capacity power electronic switching devices, and initiate silicon carbide

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
material development. These technologies allow the grid to be operated in real time to enable competitive markets, and maximize use of existing rights of way.	0	2,500	3,800
■ **Distributed Power (DP)** - Initiate multi-year cooperative efforts with industry and state energy agencies to develop innovative concepts for electric power system design utilizing distributed generation and storage resources. Identify applications and market mechanisms to realize benefits of distributed power and quantify potential benefits. Initiate activities, including modeling and case studies, for system integration tests of distributed generation and storage to examine safety, reliability, power quality, interconnect, environmental and other issues related to distributed generation and storage, and interactions of gas and electric distribution systems. With industry, draft interconnect standard for distributed generation and storage. Identify institutional barriers to the deployment and utilization of distributed resources, and develop and implement strategies for minimizing the effect of these barriers. The DP program was formulated after electric industry views on the content and priorities of the program were solicited at a workshop with broad industry representation. The level and distribution of funding in DP is appropriate to initiate the Program based on the status of research in these areas determined from industry.	0	500	200
Total, Transmission Reliability.	0	3,000	4,000

High Temperature Superconducting R&D

- **Superconductivity Partnership Initiative** - Activities will support six major projects to develop first-of-a-kind electrical systems that can provide quantum improvements to the efficiency and capacity of the national grid. These include transmission cables, transformers, large motors, flywheel energy systems and magnetic separation systems that meet performance goals. The programs's past experience has demonstrated that this extremely ambitious schedule is possible within the funding requested because of careful planning and leveraging of resources. Leveraging includes the 50% cost share that the program has been able to

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
attract, even though the projects are very high risk. Additional leveraging occurs because the project teams are typically a vertically integrated consortium of companies containing a future product use (an electric power company), a manufacturer, and a superconducting component supplier. . . .	14,000	14,500	14,000
■ **Second Generation Wire Initiative** - This effort is crucial to producing superconducting wire that meets the program's performance goals. High-performance, low-cost wire is the key to the success of the Superconductivity Partnership Initiative projects. Four industrial consortia will be working with the national laboratories to scale up discoveries that are the basis for this initiative. Wire performance goals of length, current density and cost will be met. The performance goals are very ambitious but past success indicates that the prospects are good for meeting them at the requested funding level. Private sector participants' 50% cost-sharing leverages program funds. The program has drawn upon some of the finest expertise available and feels that the requested funding will provide the resources necessary to meet program goals. .	8,000	8,000	8,000
■ **Strategic Research** - This program component has been the incubator for discoveries and innovations now being pursued in the two above initiatives. The entire program depends on continued results from in-house national laboratory research and joint research being carried out with private companies under 50% cost-shared agreements. This activity provides fundamental knowledge needed in the above two initiatives. The requested level of funding has been sufficient to provide the critical masses of multi-disciplinary research teams that have contributed breakthroughs in the past. Important research leveraging is obtained through complementary work funded by the DOE Office of Basic Energy Science, program funded work at several universities and leveraged research at the National Institute of Science and Technology (two NIST dollars for every program dollar).	9,579	10,000	9,000
Total, High Temperature Superconducting R&D.	31,579	32,500	31,000

(dollars in thousands)

FY 1998	FY 1999	FY 2000

Energy Storage Systems

- **Storage Systems Integration** - Demonstrate advanced integrated systems based on end user needs in the areas of reliability, power quality and renewables.

  Initiate one to two new Renewable Generation and Storage (RGS) projects that will produce improved integrated PV/storage hybrid systems, enabling the increased utilization of renewable generation at a lower cost and with reduced maintenance requirements.

  Continue and complete multi-year project to develop and test the Mobile PQ 2000, a state-of-the-art, transportable system that provides premium power services to commercial and industrial customers.

  Begin testing phase of ongoing Advanced Battery Energy Storage System (ABESS) project. This Technology will increase productivity and efficiency for large electricity users by allowing them to manage the costs of energy usage using low-cost, small size batteries.

  Initiate development of a new energy storage system under the Storage 2000 initiative to improve transmission and distribution stability. This new system will improve the reliability of the nation's electricity infrastructure in a competitive marketplace, and improve power quality. The funding level and program elements for systems integration were established through a series of meetings with the photovoltaic and battery industries, and a separate series of executive conferences with the electric service provider industry. 1,950 2,200 3,000

- **Key Components for Storage Systems** - Begin testing prototype power controller software that provides improved switching and optimal control strategies for hybrid (e.g. PV/diesel/storage) systems. This technology will maximize performance and reduce cost by decreasing maintenance and extending component lifetimes. Begin development of remote power systems testing requirements for international project with industrial R&D funding body. This project will greatly

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
improve the reliability of modular renewable energy systems not connected to utility grids. The funding level and identification of key components for development were established through stakeholder and industry reviews, and evaluation of the performance of existing systems. The funding level is appropriate based on industry assessments and program experience in these technologies.	1,350	1,400	2,100
■ **Analysis and Utility Competition** - Use models and engineering assessment tools to produce unbiased system studies, opportunities analyses, and technology assessments of potential high-value energy storage applications. Begin the first phase of a Handbook on Energy Storage for Renewable Systems that provides technical guidelines to members of the renewables and storage communities for improved integration of energy storage with renewables. Complete quantitative analysis of the impact of energy storage on reliability for energy providers in a restructured electricity marketplace. The funding level is appropriate based on extensive program experience in analyzing similar opportunities and benefits for application of storage technologies to enhance power quality for utility and industrial application.	539	900	900
Total, Energy Storage Systems.	3,839	4,500	6,000

Climate Challenge

■ Engage in dialogue with electric utility industry to design a voluntary program for the post-2000 period. Then renegotiate individual agreements with utilities to include voluntary utility commitments in the post-2000 period. Continue to compile and report utility industry pollution reduction accomplishments.	0	100	0

Electric and Magnetic Fields R&D

■ Completed experiments to identify the biophysical basis for replicable EMF biological effects and relevant EMF exposure parameters. Completed intensive research begun in FY 1996			

	(dollars in thousands)		
	FY 1998	FY 1999	FY 2000
to replicate key findings, using advanced EMF exposure systems at four Government laboratories. Completed a risk evaluation of potential human health effects from exposure to electric and magnetic fields (by NIEHS). Continued intensive communication program, including publication and distribution of booklets updated with most recent information. Carryover balances will be used to complete a few unfinished studies in FY 1999.			
■ In FY 1998, $1,000,000 was provided for aluminum matrix composite (AMC) conductors: Conduct utility case studies on the value of AMC conductors for increasing the capacity of transmission lines; investigate alternative materials and compositions; and investigate more efficient and economical manufacturing processes as directed by Congress.	7,844	0	0
Total, Electric Energy Systems and Storage.	43,262	40,100	41,000

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 (000)
Transmission Reliability Program	
■ Increased funding will initiate development of real time measurement systems to provide information for reliable system operation and competitive markets, and initiate Distributed Power Program.	+1,000
High Temperature Superconducting R&D	
■ The $500,000 decrease is due to a decreased number of CRADAs in the strategic research element.	-1,500
Energy Storage Systems	
■ Initiate project to develop integrated PV/hybrid storage systems; begin testing phase of the Advanced Battery Energy Storage System (ABESS) project; begin testing prototype power electronic controllers for optimum switching and control strategies.	+1,500

	FY 2000 vs. FY 1999 (000)
Climate Challenge	
■ Reduction is based on current program needs.	-100
Electric and Magnetic Field R&D	
■ EMF program completed.	0
Total Funding Change, Electric Energy Systems and Storage.	+1,900

Solar and Renewable Program Direction

Mission Supporting Goals and Objectives

Program Direction provides the Federal staffing resources and associated funding to support the management and oversight of the Solar and Renewable Energy Programs. This activity includes all funding for support service contractors, equipment, travel, crosscutting activities, and Assistant Secretary initiatives. This permits the continuation of a diverse array of Solar and Renewable projects to be integrated into a national portfolio of world renown research. Program Direction encompasses two principal activities: (1) Headquarters executive and program management; and (2) program operations at the Golden Field Office and the Idaho Operations Office.

Secretary Richardson announced in November that based on a review of the Department's staffing, the reductions had far exceeded the final FY 2000 Strategic Alignment Initiative (SAI) goals, and in fact the aggressive downsizing was now having a negative impact on technical and professional positions. As a part of the Workforce 21 initiative the Office of Energy efficiency and Renewable Energy completed a comprehensive workforce analysis for the Fiscal years 1999 and 2000, including and in-depth review of requirements for each of the component EE organizations. A total of 51% of the 155 positions that EE lost to downsizing since 1995 were technical and professional personnel, this has impaired EE's ability to deliver on its mission requirements. Further, the downsizing eliminated many lower and mid-level technical and professional employees and this is now straining EE's ability to develop successors to our retiring employees. Based on current business-as-usual staffing projections, by January 1999, 48 more technical and professional staff will be eligible for retirement, and by FY 2003 as many as 131 technical and professional employees will be eligible for retirement.

The FY 2000 Congressional Budget Request lays the foundation to off-set the adverse impacts of the downsizing. Additionally, EE has adopted smarter, more effective business and management practices, and as revealed in the workforce analysis these efforts have greatly reduced the need for most but not all of the staff lost due to downsizing. The requirements for Solar and Renewable programs could be accomplished with additional staffing above the current FY 1999 staffing levels. These new positions are consistent with EE's Workforce 21 strategy, which is to concentrate the majority of the critical hires to the technical and professional category, leaving the clerical/administrative and manager/supervisor staffing levels virtually the same.

Performance Measures

- Responsiveness to national energy policy goals and objectives.
- Continued improvement in the utilization of Federal staffing, travel, and support service contractor funding.
- Continued reductions in fiscal year-end uncosted obligations.
- Continued increase in competitive contract awards.
- Cost sharing and leveraging of program resources to enhance the program's impact.

- Improvement in environment, safety, and health compliance.
- Ensuring that all Federal employee costs, travel, support service contracts, ASEE initiatives, and crosscutting activities are supported from within Program Direction.
- Committed to creating and maintaining an environment that is free from discrimination.

Funding Schedule

(dollars in thousands, whole FTEs)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Golden					
Salaries and Benefits	1,399	1,225	1,885	+660	+53.9%
Travel	64	55	80	+25	+45.5%
Support Services	0	370	430	+60	+16.2%
Other Related Expenses	46	50	250	+200	+400.0%
Total, Golden	1,509	1,700	2,645	+945	+55.6%
Full Time Equivalents	18	15	15	0	0%
Idaho					
Salaries and Benefits	88	90	95	+5	+5.6%
Travel	0	0	0	0	0%
Support Services	0	0	0	0	0%
Other Related Expenses	0	0	0	0	0%
Total, Idaho	88	90	95	+5	+5.6%
Full Time Equivalents	1	1	1	0	0%
Headquarters					
Salaries and Benefits	8,972	8,750	9,690	+940	+10.7%
Travel	340	350	360	+10	+2.9%
Support Services	3,161	5,520	4,691	-829	-15.0%
Other Related Expenses	1,581	1,690	1,690	0	0%
Total, Headquarters	14,054	16,310	16,431	+121	+0.7%
Full Time Equivalents	98	91	84	-7	-7.8%
Total Solar and Renewable Resources Technologies					
Salaries and Benefits	10,459	10,065	11,670	+1,605	+15.9%
Travel	404	405	440	+35	+8.6%
Support Services	3,161	5,890	5,121	-769	-13.1%
Other Related Expenses	1,627	1,740	1,940	+200	+11.5%
Total, Program Direction	15,651	18,100	19,171	+1,071	+5.9%
Total Full Time Equivalents	117	107	100	-7	-6.5%

Detailed Program Justification

	(dollars in thousands)		
	FY1998	FY 1999	FY 2000
Salaries and Benefits			
■ Staff funded in this decision unit provide the executive management, program oversight, analysis, and information required for the effective implementation of the Solar and Renewable Resources Technologies Programs. The staff are also responsible for the development of policies, strategic plans and related guidance to program offices; the evaluation of program performance; the formulation, defense and execution of the Solar and Renewable budgets; and communications with the public and stakeholders regarding policies, budgets, program performance and related issues. Additionally, Solar Program Direction supports staff at the Golden Field Office and the Idaho Operations Office. Based on the completion of a comprehensive Workforce 21 analysis, additional critical professional/technical FTEs have been identified to ensure that EE's ability to deliver on its mission requirements is not impaired. EE is committed to reduce the costs for all administrative activities and achieve savings through a more streamlined and efficient management of federal staffing levels in this account. The requested FTEs are consistent with EE's Workforce 21 strategy, which is to concentrate the majority of the critical hires to the technical and professional category, leaving the clerical/administrative and manager/supervisor staffing levels virtually the same. The FY 2000 Congressional Request for Program Direction provides for staffing adjustments resulting from Workforce 21.	10,459	10,065	11,670
Travel			
■ Travel has been substantially reduced from previous years through the use of teleconferencing facilities for the conduct of oversight activities of some field organizations. The escalation of travel costs preclude further reductions without impacting EE's ability to achieve its missions requirements.	404	405	440

	(dollars in thousands)		
	FY1998	FY 1999	FY 2000

Support Services

- Includes all funding for support service contractors, equipment, crosscutting activities, and Assistant Secretary initiatives. Such activities include the development and evaluation of performance measurement and quality metrics for the Solar and Renewable Energy Programs. These activities are expected to achieve efficiency savings throughout the programs, and return to the taxpayer program cost savings far in excess of the expenditure. The support, will enable adoption of sound business practices called forth under the Government Performance and Results Act (GPRA) of 1993 and the Government Management Reform (GMRA) Act of 1994. Other support services include activities such as mailroom and travel processing.

  In FY 1999, a total of $1,900,000 is included for electricity restructuring activities including $1,500,000 in the original appropriation and $400,000 in the Omnibus Consolidated Appropriation Act. The Department is currently working on a program plan to Congress describing this new program including the discrete role the Department would play that is not duplicative of services provided by the private sector, state governments, or other Federal agencies. Also, within the $1,500,000 for restructuring, funds are provided for financial and technical assistance to states undergoing restructuring, including $150,000 for electricity restructuring activities of the California Energy Commission. In FY 2000, the electricity restructuring activities are included in the Congressional Request under Solar Program Support. 3,161 5,890 5,121

Other Related Expenses

- This activity includes the Working Capital Fund (WCF) and contractual services associated with landlord support of the Golden Field Office. Funding for the WCF in FY 1998 through FY 2000 is $1,581,000; $1,690,000, and $1,690,000 respectively. Rent is the largest component of the Working Capital Fund (FY 1998 through FY 2000 is $985,000; $926,000, and $890,000 respectively). The balance of the Other Related Expenses is for Golden landlord requirements

	(dollars in thousands)		
	FY1998	FY 1999	FY 2000
such as rental payments to GSA, expendable office supplies and materials, telecommunications and utilities, training, purchase of goods and services from Government accounts, printing and graphics, postage, maintenance and service agreements, and publications. The total costs for the Golden Office are split between the Energy Supply Appropriation and the Interior and Related Agencies Appropriation.	1,627	1,740	1,940
Total, Program Direction.	15,651	18,100	19,171

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs FY 1999 ($000)
Salaries and Benefits	
■ Increase in salaries and benefits supports general pay increases, promotions, and within-grade increases for the balance of the staff and provides for staffing adjustments resulting from Workforce 21 plans.	+1,605
Travel	
■ The increase is primarily to support travel for escalating airfare and lodging costs with offsets from alternatives to travel such as video-conferencing.	+35
Support Services	
■ Reduction results from a decrease of $1,500,000 for electricity restructuring activities conducted in FY 1999 including $150,000 for restructuring activities of the California Energy Commission and an increase of $731,000 for crosscutting activities and ASEE initiatives in FY 2000. In FY 2000, the electricity restructuring activities are included in the Congressional Request under Solar Program Support.	-769
Other Related Expenses	
■ Increased costs supports activities such as computer workstations and network infrastructure technology upgrades to improve operational efficiencies, printing and reproduction, and funding for field office rent.	+200
Total Funding Change, Solar and Renewable Program Direction.	1,071

Support Services

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Technical Support Services					
Economic and Environmental Analysis	1,611	3,190	2,600	-590	-18.5%
Feasibility of Design Considerations	0	0	0	0	0%
Total, Technical Support Services	1,611	3,190	2,600	-590	-18.5%
Management Support Services					
Management Studies	1,400	2,500	2,321	-179	-7.2%
Training and Education	0	0	0	0	0%
ADP Support	150	200	200	0	0%
Administrative Support Services	0	0	0	0	0%
Total, Management Support Services	1,550	2,700	2,521	-179	-6.6%
Subtotal Support Services	3,161	5,890	5,121	-769	-13.1%
Use of Prior-Year Balances	0	0	0	0	0%
Total, Support Services	3,161[a]	5,890[a]	5,121[a]	-769	-13.1%

[a]Includes all funding for support service contractors, equipment, crosscutting activities, and Assistant Secretary initiatives.

Other Related Expenses

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Training	0	0	5	+5	+100%
Working Capital Fund	1,581	1,690	1,690	0	0%
Printing and Reproduction	0	0	10	+10	+100%
Rental Space	46	50	120	+70	+140.0%
Software Procurement/Maintenance	0	0	50	+50	+100%
Activities/Capital Acquisitions	0	0	0	0	0%
Other	0	0	65	+65	+100%
Subtotal, Other Related Expenses	1,627	1,740	1,940	+200	+11.5%
Use of Prior-Year Balances	0	0	0	0	0%
Total, Other Related Expenses	1,627	1,740	1,940	+200	+11.5%

Federal Buildings/Remote Power Initiative

Mission Supporting Goals and Objectives

Program Mission

The Federal Buildings/Remote Power Initiative identifies and documents the economic benefit of using renewable energy technologies in applications that are currently cost-effective in the marketplace.

Program Goals and Objectives

Over the course of the Initiative, the program will demonstrate that renewable energy technologies are economical, reliable, and easy to operate.

Strategic Approach

The Federal building portion of the initiative provides financial cost-sharing assistance to Federal agencies that are seeking to incorporate renewable energy technologies into their power supply porfolio, such as wind development in San Clemente Island, California, solar domestic hot water collectors in Pearl Harbor, Hawaii; and geothermal gradient technologies at the Naval support facility in Diego Garcia. The Remote power portion of the initiative works to deploy renewable technologies--including solar, wind, fuel cell, and biomass power--in remote areas of the United States, and to develop and demonstrate their reliability, economics, and environmental benefits when compared to diesel generators.

Program Benefits

The Federal Buildings/Remote Power Initiative is supportive of the specific program mission, goals and objectives, and benefits of the participating technologies. In FY 2000, those specific sections are indicated in the individual requests of those participating technologies and in the Competitive Solicitation section of the Solar Program Support request.

Significant Accomplishments and Program Shifts

FY 1998 Accomplishments

- More than 70 applications were submitted under the Federal Buildings Initiative. Awards were made to 26 proposals resulting in 277 renewable systems being installed at Federal Facilities.
- Pursuant to a competitive Remote Power solicitation, 23 projects were funded resulting in a 10 to 1 leveraging of Federal funds.

FY 1999 Proposed Accomplishments

- The Federal Buildings Initiative will solicit additional proposals which will specifically include Native American projects involving Federal facilities.

The Remote Power Initiative will conduct two project solicitations, one directed specifically toward Native American proposals for off-grid and grid-compatible projects on native lands.

Funding Schedule

(dollars in thousands)

	FY 1998	FY 1999	FY 2000	$ Change	% Change
Federal Buildings/Remote Power Initiative	4,864	4,000	0	-4,000	-100%
Total, Federal Buildings/Remote Power Initiative	4,864	4,000	0	-4,000	-100%

Detailed Program Justification

(dollars in thousands)

	FY 1998	FY 1999	FY 2000
Federal Buildings/Remote Power Initiative			
# Use financial incentives with the federal agencies at a maximum 20% cost share to leverage as much as $5 million in installed cost-effective projects. Provide technical assistance to build infrastructure for future purchases of solar energy. Prepare a report to Congress on the progress of implementing solar energy technologies in Federal agencies as directed by Executive Order 12902. Identify and fund 24 leveraged remote applications of solar and renewable energy to reduce or avoid diesel and gasoline power generation.....	4,864	4,000	0
Total, Federal Buildings/Remote Power Initiatives.	4,864	4,000	0

Explanation of Funding Changes from FY 1999 to FY 2000

	FY 2000 vs. FY 1999 ($000)
Federal Buildings/Remote Power Initiative	
# No funding is requested under this line item. Instead, a more competitive, geographically and technologically diverse initiative (which also includes activities previously implemented under the Renewable Indian Energy Resources program) is proposed under the Competitive Solicitation section of the Solar Program Support line.	-4,000
Total Funding Change, Federal Buildings/Remote Power Initiative.....	-4,000